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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAMME OF THE STANFORD MEETING

AT

STANFORD UNIVERSITY, CALIFORNIA

July 11–12, 1947

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The American Physical Society

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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

STANFORD MEETING, JULY 11–12, 1947

THE **280th meeting of the American Physical Society** will be held at Stanford University, California, on Friday and Saturday, July 11 and 12, 1947. The steady growth of the Society and of its meetings has brought us to the stage of having five sessions. The two sessions of Friday, starting at 9:30 A.M. and 2:00 P.M. respectively, will be held in the Education Auditorium of the University, and will comprise both invited and contributed papers. Contributed papers only will compose the two simultaneous sessions starting at 2:00 P.M. on Saturday, in Rooms 370 and 372 of the Physics Department.

A **Symposium on Underwater Sound** will be held in the Education Auditorium, commencing at 9:30 A.M. on Saturday. This symposium, including papers by V. O. Knudsen, C. F. Eyring, R. W. Young, Carl Eckart, and Peter Bergmann, was arranged by Carl Eckart (Director of the Marine Physical Laboratory of the University of California).

Invited papers will be given by Felix Bloch on Friday morning at 9:30, and by J. C. Slater and R. B. Brode at the beginning of the Friday afternoon session, all in the Education Auditorium.

Luncheon arrangements shall be announced at the meeting.

Prospective meetings of the Society are planned as follows: Houston, November 28–29; Chicago (in conjunction with the A.A.A.S.), December 29–31; Pasadena, January 2–3, 1948; New York (1947 Annual Meeting) January 29–31, 1948. The Acoustical Society of America will hold a national meeting in Los Angeles on December 12 and 13, 1947, and for this meeting the American Physical Society will arrange a session of invited papers.

General Rules Relating to Papers

It is stipulated in the By-Laws of the Society that no contributed paper may be accepted for presentation at any meeting of the Society unless the title and an abstract of the paper are delivered to the office of the Society not later than the closing date stated in the printed call for the meeting.

The time allowed for the oral presentation of a contributed paper is ten minutes at most.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited to the one first named in its title.) For each paper on this programme the Secretary indicates a session at which it may be presented. The presiding officer at this session may call for it when the other papers are completed, may require that it be given in shortened form, or may read it by title.

Titles and abstracts of the papers to be presented are given in the following pages. Proofs of these abstracts have not been submitted to the authors. After submission of proof the abstracts will be published in an early number of "The Physical Review."

J. Kaplan
Local Secretary for the Pacific Coast
University of California
Los Angeles, California

JUL 8 1947

PROGRAMME

FRIDAY MORNING AT 9:30

Education Auditorium

(PAUL KIRKPATRICK presiding)

Invited Paper

A1. Nuclear Radiospectroscopy. FELIX BLOCH, *Stanford University.* (30 min.)

Contributed Papers

A2. Conservation of Momentum in the Disintegration of Li^8. I. W. A. FOWLER, C. C. LAURITSEN, and T. LAURITSEN, *California Institute of Technology.*—Apparatus[1] for the introduction of radioactive materials into a cloud chamber has been employed to investigate the conservation of momentum in the β-decay of Li^8 to Be^8, which subsequently breaks up into two α-particles. The projection on the plane of measurement of the angle between the two α-particles is a measure of one component of the recoil momentum of the Be^8. Additional information is obtainable from the momentum of the electron but relatively few cases occur where both α-particles and the electron are in the plane of the cloud chamber. The Li^8 is produced by bombarding with deuterons a thin deposit of LiOH on beryllium or gold foils. The mean square of the observed momenta relative to the maximum possible momenta were 0.247 (Be foil) and 0.349 (Au foil). Corrected for scattering these become 0.204 ± 0.025 and 0.184 ± 0.034, respectively, with an average value of 0.197 ± 0.020, the probable errors quoted being statistical in origin. It will be noted (see next abstract) that the mean square momentum is twice that obtained taking into account only the emitted electrons and approximately equal to that calculated for an electron and neutrino emitted with no preferred angle of ejection between them ($\alpha=0$).

[1] T. Lauritsen, W. A. Fowler, and C. C. Lauritsen, Phys. Rev. 71, 275 (1947).

A3. Conservation of Momentum in the Disintegration of Li^8, II. E. RICHARD COHEN AND R. F. CHRISTY, *California Institute of Technology.*—Calculations in connection with the experiment of Fowler, Lauritsen, and Lauritsen on the recoil of Be^8 will be presented. The recoil momenta were normalized to the maximum recoil consistent with conservation of energy. The Fermi distribution was used for the electron energy. Distributions of recoil momentum and the corresponding mean squares were calculated for various angular correlations of electron and neutrino.

Angular correlation of electron and neutrino	$\overline{p^2}$	$\overline{p_\perp{}^2}$
Anti-parallel	1/7	1/21
Electron only	2/7	2/21
$1+\alpha\cos\theta(-1<\alpha<1)$	$(4+\alpha)/7$	$(4+\alpha)/21$
Parallel	7/7	7/21

The mean square of one component assumes no correlation of the α-particle and recoil directions. This is certainly true if the excited state of Be^8 has $J=0$ as suggested by Wheeler's analysis of $\alpha-\alpha$ scattering. Alternatively it is also true if the β-decay is allowed but unfavored as suggested in Konopinski's review article. Reasons for preferring the latter explanation will be presented. The evaluation of scattering corrections will also be discussed. This work (I and II) was carried on under contract with the Office of Naval Research.

A4. Gamma-Radiation from Be^9+H^1. C. C. LAURITSEN, T. LAURITSEN, AND W. A. FOWLER, *California Institute of Technology.*—Further investigations have been made of the resonances in the production of gamma-radiation by bombarding Be^9 with protons. Employing an electrostatic analyzer, the narrow resonance at 1060 kev has been found to have a width of 3 kev when corrections are made for target thickness (3 kev) and the spread in energy of the beam (<1 kev). No resolution of the broad resonance at 972 kev has been found and the width at half-maximum is 95 kev. Measurements of the absorption of electron secondaries using coincidence counters indicate maximum ranges in aluminum of 14 mm at 972 kev and 12.5 mm at 1060 kev. The corresponding gamma-ray energies are 7.5 ± 0.1 and 6.7 ± 0.2 Mev. Evidence has also been obtained for soft radiation of energy between 0.5 and 1.0 Mev at the 1060-kev resonance and it is assumed that the transition to the ground state of B^{10} from the compound state produced in the reaction is a double one through an excited state of B^{10} at 0.8 ± 0.3 Mev, evidence for which has been obtained before.[1] This work was carried on under contract with the Office of Naval Research.

[1] Bonner and Brubaker, Phys. Rev. 50, 308 (1936).

A5. Proton Scattering from Be^9. SYLVAN RUBIN, *California Institute of Technology.*—The angular distribution of protons scattered from a thin beryllium foil has been measured in the energy range 840 to 1110 kev, using a photographic-type scattering camera, to investigate the effect of the two γ-ray resonances of $Be^9(p,\gamma)B^{10}$ at 972 and 1060

kev. The data include the elastically scattered protons; the deuterons from $Be^9(p, d)Be^8$; and the alphas from $Be^9(p, \alpha)Li^6$. The ratio of observed yield to Coulomb scattering increases with scattering angle to a factor of 12, at 160° for 1060 kev, and to smaller values at lower or higher energy. The yield in addition to Coulomb scattering, on the other hand, decreases with scattering angle to a roughly constant value at each energy at large angles. This increased yield cannot be due to the alphas, which are about 20 percent of the total yield at 1060 kev, at 90°. The behavior of the yield in addition to Coulomb scattering indicates probable interference effects with the Coulomb scattering at small scattering angles, where they are of equal magnitude, and is evidence for this yield being resonance scattered protons. The relation of this data to the γ-ray resonances is being studied. This work was carried on under contract with the Office of Naval Research.

A6. Some Operating Phenomena Associated with the 184-Inch Cyclotron. D. C. SEWELL, L. HENRICH, AND J. VALE, *University of California at Berkeley.*—Two experiments have been performed on the 184-inch cyclotron which give a better understanding of the operation of a frequency modulated cyclotron.

First, to explain the disappearance of the beam at the radius of 82 inches several radio autographs of specially constructed probes were made. They show that the vertical height of the beam increases rapidly near the 82 inch radius, where the value of n is approximately 0.2 ($n = -(r/H)(dH/dr)$; r = radius, H = vertical component of the magnetic field). At this value of n a coupling exists between the radial and vertical oscillations of the ions which appears to be strong enough to cause the energy of the radial oscillations to be converted into the energy of vertical oscillations, thus causing the beam to be intercepted by the dee at the 82-inch radius. Second, a number of studies have been made using a synchroscope to observe the time structure of the beam current collected by the probe. The multiple pulse nature of each beam pulse seems to be explained by the radial oscillations of the beam. These oscillations are caused by the precession of the center of rotation of the ions about the true center of the system. This paper is based on work performed with the support of the Atomic Energy Commission.

A7. Cloud Chamber Study of the Particles in the Neutron Beam of the 184-Inch Cyclotron. WILSON M. POWELL, *University of California at Berkeley.*—Recoil protons and disintegrating atoms in oxygen, nitrogen, helium, and carbon appear in cloud chamber photographs made in the neutron beam from 200 million electron volt deuterons. Frequently oxygen splits up into four doubly charged particles which may be alpha-particles. In some cases a large part of the energy of the neutron appears in one of the star particles. An attempt has been made to discover the maximum energy of the neutrons in the neutron beam by observing the maximum energy of the recoil protons. Some of the protons show energies far in excess of the maximum of 120 Mev expected. The cloud chamber is 16 inches in diameter with a magnetic field of 10,000 oersteds. This paper is based on work performed with the support of the Atomic Energy Commission.

A8. Transmutations with High-Energy Deuterons in the 184-Inch Cyclotron. B. B. CUNNINGHAM, H. H. HOPKINS, M. LINDNER, D. R. MILLER, P. R. O'CONNOR, I. PERLMAN, G. T. SEABORG, AND R. C. THOMPSON, *University of California at Berkeley.*—The successful operation[1] of the Berkeley 184-inch cyclotron to produce useful beams of deuterons and helium ions of approximately 200 and 400 Mev, respectively, has made possible the radiochemical identification of many of the transmutation products of nuclei excited to very high energies. Products with atomic numbers considerably lower than that of the target were observed in every case. Thus, with 200-Mev deuterons on $_{33}As^{75}$, activities were found representative of all elements from $_{34}Se$ to $_{25}Mn$ with lower elements not excluded. Both negative beta-particle and positron (or orbital electron capture) activities are noted, indicating reactions both of multiple neutron ejection and multiple charged particle ejection. For instance, with deuterons on $_{51}Sb$ (isotopes 121 and 123) both 6.7-hour $_{48}Cd^{107}$ and 2.5-day $_{48}Cd^{115}$ were produced. For the formation of light isotopes, several different reactions are possible, since in most cases the products will not be shielded from formation through a chain of short-lived positron (or orbital electron capture) ancestors following the ejection of different combinations of neutrons and charged particles in the primary reaction. As an example from deuterons on copper, the formation of a new 8-hour iron positron emitter assigned to $_{26}Fe^{52}$ implies that four units of charge and thirteen of mass are lost in arriving at this product.

[1] W. M. Brobeck *et al.*, Phys. Rev. **71**, 449 (1947).

A9. Transmutations with High-Energy Helium Ions in the 184-Inch Cyclotron. G. T. SEABORG, B. B. CUNNINGHAM, H. H. HOPKINS, M. LINDNER, D. R. MILLER, P. R. O'CONNOR, I. PERLMAN, AND R. C. THOMPSON, *University of California at Berkeley.* In continuation of the work reported in the previous abstract, uranium was bombarded with 400-Mev helium ions, and a wide range of activities was identified both in the heavy-element region and in the region of the fission products. Representative of the heavy isotopes observed were $_{88}Ra^{223}$ (AcX), $_{88}Ra^{224}$ (ThX), and $_{85}At^{211}$. The fission-product distribution is characterized by a much shallower dip between the maxima than occurs with slow-neutron fission, and the yields of the lightest among the observed fission-products are much higher. The various aspects of this work will be published more fully by the individual groups of investigators. This work and that reported in the previous abstract were performed with the support of the Atomic Energy Commission.

A10. Angular Distribution of Neutrons From Targets Bombarded by 190-Mev Deuterons. A. C. HELMHOLZ, EDWIN M. MCMILLAN, AND DUANE SEWELL, *University of California.*—When deuterons accelerated by the 184-inch synchro-cyclotron at Berkeley to an energy estimated at 190 Mev are allowed to strike a thin internal target, copious quantities of high energy neutrons are produced. These are found to be largely concentrated in a beam of

about 10° half-width (total width at half maximum). The shape of this beam has been studied in some detail, using the activity induced in carbon disks by the reaction $C^{12}(n, 2n)C^{11}$ as a measure of the intensity; by this means a complete map of the beam is obtained with a single exposure, and the relatively high threshold of the reaction (20 Mev) automatically eliminates any background due to secondary or degraded neutrons below this energy. The targets used as neutron sources were of Be, Al, Cu, Mo, Sn, Ta, and Pb, all $\frac{1}{16}$ inch thick. The shape of the neutron beam is the same for all elements, being well represented by the function $I=(1+\alpha\theta^2)^{-1}$, where θ is the angle from the axis of the beam and α is a constant characteristic of the target. The half-widths, however, vary significantly from target to target, increasing roughly linearly with atomic number from 0.16 radian for Be to 0.21 radian for Pb. Both shape and half-widths are in good agreement with the theory of Serber (following abstract). This work was done with the support of the Atomic Energy Commission.

A11. Production of High Energy Neutrons by Stripping, I. Energy Distribution. R. SERBER, *University of California at Berkeley.*—The narrow beams of high energy neutrons, described in the preceding abstract, which result from the bombardment of nuclei by high energy deuterons are for the most part produced by a process in which the deuteron passes near the edge of the nucleus, the proton strikes the nucleus and is stripped off, while the neutron misses the nucleus and continues with almost the velocity of the incident deuteron. The cross section for this process is $\sigma=\frac{1}{2}\pi RR_d$, where R is the nuclear radius, and $R_d=(\frac{1}{2}M\epsilon_d)^{\frac{1}{2}}=2.1\times10^{-13}$ cm is the deuteron radius (M is the proton mass, ϵ_d the binding energy of the deuteron). Since for the high deuteron velocities involved the time required for the stripping is short compared to the period of the deuteron, the neutron emerges from the collision with its momentum unchanged. The momentum is, of course, the resultant of the momentum due to the center of mass motion, $P_0=(ME_d)^{\frac{1}{2}}$, and the momentum of its motion within the deuteron. The probability distribution of the latter quantity can be found by Fourier analysis of the deuteron wave function, subject to the condition that the proton hits the nucleus and the neutron misses. The emergent neutrons will have energies mostly in the band $(\frac{1}{2}E_d\pm20$ Mev).

FRIDAY AFTERNOON AT 2:00

Education Auditorium

(L. A. DUBRIDGE presiding)

Invited Papers

B1. Some Applications of Microwaves to Physics. J. C. SLATER, *Massachusetts Institute of Technology.* (30 min.)

B2. Cosmic Rays. R. B. BRODE, *University of California at Berkeley.* (30 min.)

Contributed Papers

B3. Nuclear and Molecular Information from Microwave Spectra. C. H. TOWNES, A. N. HOLDEN, AND F. R. MERRITT, *Bell Telephone Laboratories.*—In addition to previously reported work[1] the spectra of $O^{16}C^{12}S^{34}$, $O^{16}C^{13}S^{32}$ and $Cl^{35}C^{13}N^{14}$ near 24,000 megacycles have been examined. Internuclear distances will be discussed. No quadrupole effects were observed for C^{13} or S^{34}. The quadrupole coupling $(eQ\partial^2V/\partial z^2)$ of C^{13} in the above molecules cannot be greater than 0.5 mc, which further[2] supports a spin of $\frac{1}{2}$ for C^{12}. Coupling for S^{34} is less than 1 mc, indicating that zero spin is probable. An evaluation of $\partial^2V/\partial z^2$ may be obtained for heavy nuclei bonded in a molecule by one or two p bonds. In these cases the non-spherical p electron shell produces a very large $\partial^2V/\partial z^2$, other effects being negligible. Evaluation of $\partial^2V/\partial z^2$ and use of quadrupole coupling values[1] give the following quadrupole moments in units of 10^{-24} cm^2. $Cl^{35}=-0.067$, $Cl^{37}=-0.051$, $Br^{79}=0.21$, $Br^{81}=0.16$, $|S^{34}|\leq.001$. Quadrupole couplings can also be used with known quadrupole moments to determine the importance of non-spherical p structures in molecular bonds.

[1] Townes, Holden, Bardeen, and Merritt, Phys. Rev. 71, 644 (1947).
[2] Jenkins, Washington Meeting Am. Phys. Soc., paper L12 (1947).

B4. Loading of Resonant Cavities by Electron Beams. WAYNE G. ABRAHAM, *Stanford University.*—The shunt impedance of a resonant cavity is changed when an electron beam is passed through it in the direction of the electric field, as for instance in resonators for velocity modulation tubes. In cavities with grids the reduction in shunt resistance is found to be greater than theory would predict on the basis of finite transit time, resulting in undesired losses. This anomalous "beam loading" has been shown experimentally to be due to two factors, each a result of secondary emission. The first is due to the absorption of energy by the secondaries before they leave the grid space. The second occurs under certain conditions because of

multiplier action of electrons making successive transits of the grid space in a manner sometimes called "multipactor action." By the elimination of all secondary emission, the beam loading has been shown to agree with that predicted by transit time theory.

B5. Ultra-Short Duration Flash Radiographs. J. C. CLARK, *Los Alamos.*—The duration and nature of the bursts of x-rays produced by the high speed flash radiographic equipment described by Slack and Ehrke have been studied by radiographing a very thin strip of lead cemented to a piece of explosive of high detonation velocity as the detonation proceeds. Such radiographs show that bursts of x-rays varying in duration between 1 and 3 microseconds are produced and that they are, in general, multiple in character, indicating an interrupted or oscillatory type of discharge through the x-ray tube. For many purposes a single burst of x-rays of much shorter duration is desirable. By studying the method of initiation of a cold cathode, Slack type tube, a circuit has been assembled which operates satisfactorily at relatively low voltages (60–100 kv), producing a single x-ray burst of duration 10^{-7} second, as measured by the same timing method.

B6. Ultra-Fast Counters. S. H. NEDDERMEYER, *University of Washington.*—A device has been described[1] which is capable of measuring the time interval between two pulses to an accuracy of about 3×10^{-11} sec. Useful application of the existing instrument for the measurement of particle velocities could probably be made with a vacuum multiplier type counter having a multiplication factor in the vicinity of 5×10^{9} and an effective capacitance of 10 e.s.u. Variation in over-all transit time, possible delayed emission, and matching conditions for the line are important, apart from the multiplication factor itself. Some of the possibilities and difficulties will be discussed.

[1] Phys. Rev. 69, 702 (1946). Paper to be published in Rev. Sci. Inst. July (1947).

B7. The Measurement of Short Time Intervals. LUIS W. ALVAREZ, *University of California at Berkeley.*—Modern "spectrum analyzers" present on a cathode-ray tube the frequency spectrum of repeated video pulses. The same pattern could be shown for a single pulse if a number of tuned receivers were used with appropriate delay lines in their outputs. For the gaussian pulse from a 931 electron multiplier, the spectrum would be gaussian with large signal-noise ratio beyond 1000 mc.[1] Receiver gains could be adjusted to show an apparently flat spectrum from 0 to 1000 mc for a single pulse. Then if two pulses with amplitude ratio n occurred with time delay T, the spectrum would have the form $1+n\cos 2\pi fT$. (For $T=2\times10^{-9}$ sec., minima at 250 and 750 mc.) By observing this "interference pattern," one measures T. At frequency f, the phase shift of the pattern is $2\pi f\Delta T$, independent of T. (For $f=10^{9}$ and $\Delta T=10^{-10}$ sec., $\Delta\phi=36°$.) With receiver spacing Δf proportional to f, the minimum detectable ΔT is a constant fraction of T and can be 0.1 in practice. ($\Delta T=10^{-10}$ for $T=10^{-9}$.) Receiver bandwidth has no effect on ΔT, which is determined by f max. Measurement will be by analysis of photographs, but automatic methods could be devised. This work was done under the auspices of the Atomic Energy Commission.

[1] R. D. Sard, J. App. Phys. 17, 768 (1946).

B8. Corona from Water Drops. W. N. ENGLISH, *University of California at Berkeley.* (*Introduced by Leonard B. Loeb.*)—A capillary tube as used by Zeleny provides a liquid "point" in a point to plane corona gap and permits further investigation of the effects described by Macky for falling drops, by using positive and negative polarity. Photographic records of oscillograph pulses, and of the liquid point with and without argon flash lamp illumination make possible a study and interpretation of the effects in the light of recent corona theory.[1] In brief, the regular corona processes appear to be superimposed on effects due to the ejection of charged drops of liquid. With positive point and increasing voltage, three distinct regions are observed. In the first, streamer pulses are superimposed on "spray" pulses of about 1000 microseconds duration because of the ejection of very fine drops, as observed by Macky. At higher voltage, positive space charge due to streamers and burst corona so weakens the field at the point that ejection of liquid ceases and the drop becomes rounded and stable. At still higher voltage, the liquid surface is violently disrupted and large drops ejected which quickly wet the plane electrode. With a negative point, trichel pulses are observed, followed closely by "spray" pulses somewhat similar to those for positive point, with trichel pulses superimposed. These increase in frequency and, to some extent, in amplitude, just as for negative metal points, while the ejection of water and luminosity spreads over the end of the capillary. No stable region occurs.

[1] L. B. Loeb and A. F. Kip, J. App. Phys. 10, 142 (1939).

B9. Dust Electrostatics. JAMES W. HANSEN, *University of California at Berkeley.* (*Introduced by Leonard B. Loeb.*)—The apparatus used by Hopper and Laby to study the charge on oil drops has been redesigned to study the charge on dust particles in the size range of 50 to 1 micron in diameter. By this method photographs of a large number of tracks can be obtained, allowing the use of statistical methods in determining relationships. Using sulfur dust in a sulfur coated tube and finely ground quartz in a quartz tube, it has been shown that a dust can become highly charged by frictional contact with a surface of the same material. Charges of both signs exist simultaneously in the same cloud and the charge per particle varies enormously over a wide range. A definite relation seems to exist between the size of the particle and the charge which it carries, large charges occurring on large particles. A tentative hypothesis is advanced, based on the formation of aggregates, to explain this relationship. The theoretical selectivity of measurement of the apparatus has been investigated mathematically and has indicated nothing to show that such a relationship between particle size and charge is instrumental and not real.

B10. On the Radiation of Sound from an Unflanged Circular Pipe. HAROLD LEVINE AND JULIAN SCHWINGER, *Harvard University.*—A rigorous and explicit solution has been obtained for the problem of wave propagation in a semi-infinite unflanged circular pipe, which is valid throughout the wave-length range of the dominant mode. In addition to the determination of the reflection coefficient within the pipe, the power gain function, embodying the characteristics of the radiation pattern, is calculated explicitly. A reciprocity theorem is derived which relates the absorption cross section of the pipe for a plane wave, incident from the external space, to the gain function for this direction. In particular, the absorption cross section for a wave incident normally on the mouth is simply the geometrical area. When the wave length of the sound vibrations is large compared to the diameter of the pipe, the dominant mode velocity potential is the same as if the pipe were lengthened by a certain fraction of the radius and the open end then behaved as a loop. The rigorous value of this end correction is found to be 0.6133, and supplants the experimental estimates of Rayleigh[1] (0.6), Boehm[2] (0.656) and Bate[3] (0.66).

[1] Lord Rayleigh, *Theory of Sound, II*, Chapter 16 and Appendix A.
[2] W. M. Boehm, Phys. Rev. **31**, 341 (1910).
[3] A. E. Bate, Phil. Mag. **10**, 617 (1930); **24**, 453 (1937).

B11. A Variational Principle for Scattering Problems. JULIAN SCHWINGER, *Harvard University.*—A reformulation of the general scattering problem, in terms of a variational principle, has been devised. An explicit expression is obtained for the elements of the scattering matrix, which has the property of being stationary with respect to variations relative to the correct wave function. When combined with various techniques for obtaining approximate trial functions, and an iteration procedure for systematic improvement of the trial function, the use of the variational principle provides a powerful method for the solution of scattering problems. The author has applied the method extensively to wave guide problems-neutron diffusion questions have also been attacked in this manner. A discussion will be given of the variational treatment of proton-proton and neutron-proton scattering. By employing as a trial wave function that appropriate to some convenient fixed energy, approximate but accurate scattering formulae are obtained, which exhibit the energy dependence of the cross section without explicit specification of the radial dependence of the interaction. The analysis of scattering experiments is thereby simplified. The proton-proton scattering data, in particular, will be discussed.

SATURDAY MORNING AT 9:30

Education Auditorium

(L. B. LOEB presiding)

Symposium on Underwater Sound

C1. Sounds in the Ocean. VERN O. KNUDSEN, *University of California (Los Angeles).* (30 min.)

C2. Reverberation in the Sea. CARL F. EYRING, *Brigham Young University.* (30 min.)

C3. Transmission of Sound in the Sea. R. W. YOUNG, *U. S. Navy Electronics Laboratory, San Diego.* (30 min.)

C4. Coherence of Scattered Sound. CARL ECKART, *University of California (Marine Physical Laboratory).* (30 min.)

C5. Fluctuation of Transmitted Sound. PETER BERGMANN, *Bureau of Ships, U. S. Navy.* (30 min.)

SATURDAY AFTERNOON AT 2:00

Room 370, Physics Department

(J. KAPLAN presiding)

D1. A Cloud-Chamber Study of the Ionization By High Energy Cosmic-Ray Electrons. EVANS CLEMENT, *University of California at Berkeley.*—The ionization produced by high energy cosmic-ray electrons has been measured in a cloud chamber in order to determine whether the ionization produced by a high velocity particle continues to rise with the energy or whether it takes on a constant value as has been predicted theoretically. A lateral clearing field was arranged so that the ionization could be measured in the upper half of the cloud chamber; lead plates were placed in the lower half so that the electron would produce a shower from which its energy could be estimated. The ionization produced by electrons was measured and compared to the minimum ionization as determined from the

average ionization produced by mesotrons. According to the theoretical formula of Halpern and Hall the maximum ionization should be 1.4 I_{min}. In most of the pictures taken the ionization was consistent with this value. There were several pictures, however, where the ionization was extremely high. These may either indicate that the theoretical formula is invalid, or they may result from the coincidence of two or more particles. If a high energy pair is produced just above the cloud chamber, the tracks may be superposed in the cloud chamber.

D2. Cosmic Ray Tracks in Photographic Emulsions Produced at High Altitudes.* HARRIET H. FORSTER, *University of California at Berkeley.* (*Introduced by Robert B. Brode.*)—Kodak "fine grain alpha-particle" plates and Ilford "Nuclear Research" plates with an emulsion thickness varying from 25μ–100μ have been exposed to cosmic radiation both at sea level and at high altitudes. High altitude exposures were made on a number of B-29 flights at Inyokern, California, at an average height of 35,000 feet. The exposures were made on a pile of plates consisting of from 1 to 6 pairs. In each pair the emulsion sides of the plates were facing each other. The pile was wrapped in black paper and sealed in a cardboard box. Exposure times were varied from 1 to 30 hours. Single particle trajectories and multiple branchings with up to 6 tracks have been observed and directional effects have been investigated. A large increase in the number of nuclear events with increasing altitude has been found, this effect being especially marked for higher energy processes, e.g., nuclear disintegrations.

* The research described in this abstract was supported in part by the Office of Naval Research.

D3. Further Measurements on the Mass of the Mesotron.* J. G. RETALLACK, *University of California.*—W. B. Fretter[1] has reported 26 measurements of the mass of the mesotron with probable errors of individual measurements about ±30 electron masses. The experiment is being repeated with some improvements. To improve the measurement of curvature in a magnetic field, the chamber is surrounded by a water cooled (±0.35°C) copper shield. A symmetrical arrangement of 3 exhaust ports has reduced spurious curvatures of 30 no-field tracks; 20 have radii of curvature greater than 35 meters, and 10 have radii about 20 meters. To improve the measurement of range, 15 lead plates ¼ inch thick have been placed in a chamber in the shape of a truncated pyramid. Thus, mesotrons stopped in the chamber will be readily identified by the increased ionization over the plate in which it stops. The illuminated region is 6 inches deep and 20 inches square. The Geiger counters define a cone requiring 4 inches depth.

* The research described in this abstract was supported in part by the Office of Naval Research.

[1] W. B. Fretter, Phys. Rev. **70**, 625 (1946).

D4. Temperature Coefficients of Cosmic-Ray Components. D. H. LOUGHRIDGE AND F. M. MILLICAN, *University of Washington.*—Studies of data from a cosmic-ray telescope and atmospheric "mass temperatures" from Raob soundings have yielded temperature coefficients for hard (30-cm lead), medium (10-cm lead), and soft (½-cm lead) components. These coefficients increase with increasing fractions of the atmosphere for the hard and medium components. Preliminary results are: Hard, −.19±.02 percent/°C, −.19±.02, −.24±.02, and −.29±.04 for the fractions ¼, 6/10, ¾, and 1, respectively: Medium, −.20±.04 percent/°C, −.22±.03, −.26±.04, and −.35±.07, respectively. The average correlations are .85±.04 and .67±.08, respectively. Correlations fall off as fractions less than ¼ whose temperatures approach surface values are taken. The soft component correlations are so low results are not quoted. There is some indication that the coefficient is positive and that correlations improve as surface temperatures are approached. The hard and medium coefficients show good proportionality to the average value of $[\partial Z/\partial T]_f$ obtained by assuming that an increase in intensity is linearly proportional to a downward shift in air mass as suggested by Benedetto.[1] Preliminary analysis of data from a Millikan-Neher type meter with 12-cm lead shielding gives coefficients of the same order of magnitude varying similarly to the hard and medium telescope results for atmospheric fractions from ½–1.

[1] F. A. Benedetto *et al.*, Phys. Rev. **61**, 266 (1942).

D5. Propagation of Cosmic Rays through Interstellar Space. JAMES W. FOLLIN, JR., *California Institute of Technology.*—An investigation has been made of the interaction of high energy particles with interstellar matter and radiation to determine the range of such particles. The most important such interaction is the loss of energy by energetic electrons through a Compton scattering process (this is easily seen in a coordinate system moving with the electron). The transverse acceleration in a stellar magnetic field causes radiation of energy* and this is important if the source is in or near a star. The origin of cosmic-ray particles is not known and several hypotheses have been examined. The results are strongly affected by the possibility of a general gallactic magnetic field; unfortunately the problem of its existence is completely unsolved. The conclusion reached is that there should be few primary electrons with energy greater than about 10^{12} ev, but until the origin is determined this result cannot be considered final.

* Pomeranchuk, J. Phys. Acad. Sci. U.S.S.R. **2**, 65 (1940).

D6. Penetrating Showers Produced in Lead at Sea-Level.* W. B. FRETTER, *University of California at Berkeley.*—The penetrating showers produced by cosmic rays in lead at sea level have been observed in a counter-controlled cloud chamber containing eight one-half-inch lead plates. Several showers were observed that contained only penetrating particles, but in others electronic particles were simultaneously produced in varying amounts. Production of electrons appears to be characteristic of the higher energy events. It may be possible to explain the simultaneous production of penetrating particles and electrons by following the suggestion of Oppenheimer and postulating the production of very short-lived neutral mesons that decay to give the soft radiation. Absence of the electronic radiation in low energy events may then be explained by fluctuations and the inability of low energy soft radiation to penetrate the lead plate in which the event occurs. Large angular

spread (usually about 30°) of the penetrating particles is characteristic of these events, in contrast to the highly collimated core of electronic showers. Primary particles penetrating the atmosphere may be responsible for the showers observed, since the frequency of observed events is not inconsistent with the expected number of primaries at sea level as estimated from the free path of primaries in the atmosphere.

* The research described in this abstract was supported in part by the Office of Naval Research.

D7. Stars in Photographic Emulsions Produced by Particles Accelerated by the Cyclotron. EUGENE GARDNER, *Radiation Laboratory, University of California at Berkeley.*—Alpha-particles and deuterons accelerated by the 184-inch Berkeley cyclotron are being studied with the aid of commercial photographic plates made especially for charged particle studies. The plates are exposed to the circulating beam inside the cyclotron tank. The particle trajectories do not, in general, lie in the emulsion for their entire range; however, it is possible to study sections of tracks which correspond to known energies by making observations near the edge where the beam enters the emulsion. Sections of tracks corresponding to various energies are obtained by exposing plates at various radii in the cyclotron. Some alpha-particle tracks are observed to branch into two or more tracks. This branching, or star formation, is attributed to a disintegration of some nucleus in the emulsion. For stars formed by alpha-particles, the track of the initiating particle can ordinarily be seen, and the track is particularly clear for energies of 200 Mev or lower. For stars formed by deuterons we are not able to see the track of the initiating particle. This paper is based on work performed with the support of the Atomic Energy Commission.

D8. Balanced Ionization Chamber for Differential Measurements of Gamma-Rays. CLYDE WIEGAND, *University of California at Berkeley.* (*Introduced by E. Segrè.*)—In connection with an investigation[1] on the half-life of beryllium, it was important to have an apparatus that could measure small differences of strong gamma activities. Such an apparatus was constructed. It consists of two equal ionization chambers connected to a single electrometer. The arrangement of the circuit is such that ionization current produced in one chamber tends to cancel the ionization current produced in the second chamber. The electrometer uses a conventional circuit employing an FP-54 tube. As a test of its performance and as another application, the half-life of Be^7 (52 days) and of 106-day Y were determined by measuring the variation of their activity against that of a radium standard. In a time of the order of 1/100 of the half-life it was possible to measure the half-life to an accuracy of ±4 percent by using a sample equivalent in gamma-activity to 50 μg radium. It was found that the fluctuations observed in the actual balancing of the chambers was that to be expected on a statistical basis due to the discontinuous nature of radioactive emission. This paper is based on work performed with the support of the Atomic Energy Commission.

[1] E. Segrè, Phys. Rev. **71**, 274 (1947).

D9. A Vacuum X-Ray Spectrometer.* S. T. STEPHENSON AND F. D. MASON, *Washington State College.*—A vacuum x-ray spectrometer is described which is suitable for use as a single or double crystal instrument in the region out to 15A. Novel features in this vacuum instrument include: the flexibility of either single or double crystal techniques, Geiger counter detection of intensities with the counter driven by a synchronous motor, and automatic recording of the Geiger counter output. The double crystal arrangement is of the Ross[1] type which allows the x-ray tube and the mount for crystal *B* to be stationary. A slit system replaces crystal *A* for single crystal work. The Geiger counter design provides a very thin window supported on both sides so that it will not blow in when exposed to air nor out when in the spectrograph. Preliminary results on the performance of the instrument will be presented.

* This work has been carried out under a contract with the Office of Naval Research.

[1] P. A. Ross, Rev. Sci. Inst. **3**, 253 (1932).

D10. Cosmic Rays as Products of Radioactivity. GERTRUDE SCHWARZMANN.—Interpreting particle waves as alternating currents with direct current components, decomposition of a light wave into two alternating currents with opposite direct current components as materialization, the reverse wave phenomenon as dematerialization, allows of interpreting formation and decay of compounded nuclei as follows: Two light waves, revolving in opposite senses about each other, decompose into component light waves, decomposing in turn each into a proton pair or electron pair. Formation of neutrons, consisting of negatron and satellite positron, prevents redematerialization of equal numbers of proton pairs and electron pairs, the more so because both constituents of stable neutrons are assumed to be in the corpuscle-state. The original nucleus consists of Z protons and Z neutrons. Electron-capture by individual protons somewhat upsets the equilibrium of the nucleus. Its alpha-decay originates in simultaneous positron-decay of n neutrons revolving clockwise and of n neutrons revolving counterclockwise, followed by simultaneous dematerialization of $2n$ proton pairs. Outside the parent nucleus production of two multi Bev cosmic rays, each resultant of the superposition of n light waves revolving in the same sense, competes with the formation of an alpha-particle of atomic number $2n$.

D11. A Non-Homogeneous Cosmological Model. GUY C. OMER, JR., *California Institute of Technology.*—The non-homogeneous cosmological models with spherical symmetry and zero pressure first used by Lemaitre[1] and Tolman[2] have been integrated exactly. The special solutions with a zero cosmological constant are applied to the cosmological problem. If we assume, as a first approximation, that the observer is near the center of the universe, the following three relations are readily evolved: (1) The observed red-shift for a source at a stated coordinate. (2) The total number of nebulae which are contained within a sphere of stated coordinate radius. (3) The observed magnitude for a source of known luminosity located at a stated coordinate. It is then shown that a M_1 model which is nearly homogeneous throughout the observable

range agrees with the observations within the experimental error.

[1] G. Lemaitre, Ann. Soc. Scient. de Bruxelles, **A53**, 51 (1933).
[2] R. C. Tolman, Proc. Nat. Acad. Sci. **20**, 169 (1934).

D12. Electronic Energy Levels in Simple Crystal Models. DAVID S. SAXON AND REINA A. HUTNER,* *Philips Laboratories, Inc., Irvington, New York.*—The use of simple crystal models as an aid to the understanding of electronic processes in crystals has not been as extensive, perhaps, as might be expected in view of the difficulty of calculations for real crystals. As is well known, these processes depend only quantitatively on the detailed properties of the crystal; most of the characteristic features are retained even in the most highly simplified models.[1] An attempt has been made therefore systematically to examine these characteristic features by using one dimensional models of a crystal in which the lattice potential consists of a series of Dirac δ-functions. The problems which have been or are being studied include the following: The wave functions and energy levels in pure crystals—polyatomic as well as monatomic; the scattering, wave functions and energy levels associated with impurities in the crystal lattice; the interaction between impurity states; solid solutions; conductivity. In addition the problem of extending these results to more realistic potentials and to models of two and three dimensions is being studied.

* Now at University of California, Los Angeles.
[1] See for example, Kronig and Penney, Proc. Roy. Soc. **130**, 499 (1931).

D13. Character of the Radiation Field and Shielding at the 184" Cyclotron. B. J. MOYER, R. HILDEBRAND, N. KNABLE, T. J. PARMLEY, AND H. YORK, *University of California at Berkeley.*—Absorption experiments with ionization chamber detection using various absorbing materials in the fast neutron beam (~100-Mev max.) have shown transition effects followed by approximately exponential reduction in ionization with increasing absorber thickness. Data will be presented on the transition effects with various arrangements of materials and on the exponential absorption coefficients. A brief summary of these data follows: (1) If the neutron beam first passes through an equilibrium thickness of some material and then enters a variable thickness of absorber of lower atomic number, the transition effect will be "positive," i.e., there is an increase in ionization due to a greater yield of recoil and exchange protons from the second medium than from the first. (2) The absorption cross section per atom increases, but its value per proton decreases with increasing Z. Data taken with carbon detectors using the $C^{12}(n, 2n)C^{11}$ reaction show similar absorption but without transition effects. Measurements will be reported on the effectiveness of the five-foot concrete shielding, and on the composition of the external radiation field with respect to its content of gamma-rays, neutrons, and secondary particles. Acknowledgment is due to Dr. F. Oppenheimer for information contributed from related experiments. This work was done under the auspices of the Atomic Energy Commission.

D14. Cu^{60} Radioactivity. C. E. LEITH, ALEC BRATENAHL, and B. J. MOYER, *University of California at Berkeley.*—A β^+, γ-activity of 24.5 minute half-life has been discovered and assigned to Cu^{60}. It has been produced by the reactions $Ni^{60}(p, n)$, $Ni^{60}(d, 2n)$, and $Ni^{58}(\alpha, pn)$. The target materials were isotopically enriched by the calutron process. Protons of energies up to 15 Mev produced in the 37-inch frequency modulated cyclotron were used for the first reaction, 18-Mev deuterons and 36-Mev alpha-particles produced by the 60-inch cyclotron for the others. The β^+ energy has been measured by absorption in Al as 1.8 Mev. The γ-energy has been measured by absorption in lead, using Co^{60} γ-absorption for calibration as 1.3 Mev. Chemical separation of Cu from the Ni target after proton bombardment assigned the activity to Cu, and separation of target isotopes in a calutron immediately after bombardment showed that this isotope must be 60. The proton threshold energy for the $Ni^{60}(p, n)Cu^{60}$ reaction lies between 4 and 5 Mev. Recognition is due to R. E. Butler who contributed to the early efforts in this study, and to Robert Lilly for the chemistry involved. This paper is based on work performed with the support of the Atomic Energy Commission.

SATURDAY AFTERNOON AT 2:00

Room 372, Physics Department

(K. K. DARROW presiding)

E1. Sensitive d.c. Current-Amplifier Operated from a.c. SEVILLE CHAPMAN, *Stanford University.*—A simple three-stage amplifier made from ordinary parts except for an input resistor of 10^{12} ohms (or less) connected to the second (control) grid of a ($12.50) Victoreen VX-41 electrometer tube is described. Its grid current is less than 2×10^{-15} ampere. Other tubes are Raytheon CK505 and CK507. Input capacitance is about 8 micromicrofarads. The amplifier is a.c. operated, a total of 50 ma d.c. current including filament current is provided by a conventional 150-volt regulated supply. A 0–100 microammeter is in a bridge circuit in the CK507 plate circuit. The amount of negative feedback (usually about 10 db) from the CK507 plate to the first (space charge) grid of the VX-41 is controlled by a variable resistor in series with the meter, thus the zero reading is unaffected by adjustment of gain. A deflection of 100 microamperes requires +0.0330 or −0.0335 volt. Without voltage regulation, supply voltage

variation of one volt deflects the meter less than 20 microamperes. Initial drift after a 20-minute warm-up is about 50 microampere/hour; 24 hours later, 5 microampere/hour. Random meter fluctuations correspond to a fluctuating input current of about 2×10^{-16} ampere.

E2. The Sound Pressure in Water Resulting from a Point Source in Air.* E. GERJUOY, *University of Southern California.*—If a point source is placed in air above an infinite flat water surface, rays leaving the source within a cone of 13° are refracted at the surface, with increasing divergence as the angle of incidence approaches the critical angle, so that directly transmitted energy reaches every point in the liquid. Rays outside the 13° cone are totally reflected. The directly transmitted pressure can be calculated by ray acoustics, and varies as the inverse fourth power of the distance from the source, for points near the surface and far from the source. In the region of total reflection there is also a term decreasing exponentially with distance from the surface. Since the pressure at the surface varies as the inverse square of the distance from the source, a hydrophone within a wave-length of the surface, in the region of total reflection, should respond to the exponentially decreasing term, rather than to the directly transmitted pressure. This experiment would be a quantitative and less ambiguous demonstration of penetration of fields into the second medium in total reflection than the analogous optical experiments which are usually performed with beams of finite cross section. For such beams energy necessarily penetrates the second medium.

* This paper is based in part on work done for the Office of Scientific Research and Development.

E3. The Vertical Reflection of Supersonic Sound from the Sea Bottom. R. W. RAITT, *Marine Physical Laboratory,** *University of California.*—The manner in which supersonic sound is reflected from the sea bottom is being investigated by studying the echoes received with sound beams of 18 kc and 24 kc frequency directed vertically downwards. Although the theory is not clearly understood, preliminary results have served to decide between two hypotheses: (1) The bottom reflects sound like a flat mirror, so that the echo is a replica of the emitted pulse. (2) The bottom reflects the sound diffusely, so that the insonified area returns many echoes; these will return to the receiver at different times and the echo will be elongated and distorted; varying phase displacements between these component echoes, caused by the motion of the receiving ship, will be expected to produce fluctuation of the echo shape; the average shape of the echo will depend on the geometry of the sound beam and on the angular dependence of the bottom scattering coefficient. From many observations, covering a wide variety of bottoms off California, no echoes of the type expected on hypothesis (1) have been observed. All of them exhibit the properties expected on hypothesis (2).

* This work represents one of the results of research carried out under contract with the Bureau of Ships and Office of Naval Research, Navy Department.

E4. An Acoustic Interferometer for the Measurement of Sound Velocity in the Ocean. R. J. URICK, *Naval Research Laboratory.**—A fixed-path variable-frequency acoustic interferometer has been developed which is capable of recording small changes of sound velocity as the instrument is lowered from a surface vessel. Simultaneous measurements of velocity and water temperature have been made near the surface of the ocean. Good general agreement is observed between the velocity-depth plots obtained with the interferometer and those computed from bathythermograph and thermopile observations for sea states of 0 to 3 and for depths as great as 150 feet. A velocity microstructure is frequently recorded which deviates as much as $\frac{1}{10}$ percent from the velocity obtained from bathythermograph observations, but which is in good agreement with the temperature microstructure observed with a thermopile recorder.

* This work was performed while at the USN Electronics Laboraotry, San Diego, California.

E5. Electrostatic Analyzer for 1.5-Mev Protons. T. LAURITSEN, W. A. FOWLER, AND C. C. LAURITSEN, *California Institute of Technology.*—An electrostatic deflector has been constructed and used to analyze the proton beam of a 1.5-Mev statitron. The analyzer consists of two plates curved through 90° on a 1.1 meter radius and separated by 8.6 mm. Fields up to 30 kv per cm are maintained by a transformer-rectifier power supply electronically regulated to a few hundredths of one percent. The proton beam from the generator, defined by a 0.5-mm aperture, is first subjected to a coarse magnetic analysis to separate out mass 2 and heavier components and then passes into the electrostatic deflector through a 1-mm slit. After analysis the beam emerges through an 0.7-mm slit provided with insulated jaws which control an auxiliary corona load on the generator and automatically correct the voltage to keep the beam central in the slit. The system has been in operation for a number of months in the neighborhood of 1 Mev and has yielded resolution of better than 1 kev at currents of the order of 1 μa. This work was carried on under contract with the Office of Naval Research.

E6. Cobalt 61 Radioactivity. THOMAS J. PARMLEY AND BURTON J. MOYER, *Radiation Laboratory, University of California at Berkeley.*—Isotopes of Ni^{61} and Ni^{62} were subjected to fast neutron bombardment from the Crocker Laboratory 60-inch cyclotron. Among the activities produced was a $1.75\pm.05$ hour half-life associated most strongly with the Ni^{61} sample. Chemical extractions showed this activity belonged to cobalt. The mass assignment was established as follows: (1) Electrolytic copper was activated with fast neutrons. The cobalt extraction yielded a 1.75-hour half-life activity. (2) Calutron analysis of neutron activated electrolytic copper placed this activity in 61-mass position. (3) Normal nickel was bombarded with 22-Mev deuterons followed successively by cobalt separation and calutron analysis. The 1.75-hour activity appeared in 61-mass position. Ni^{64} was bombarded with 14-Mev protons from the 37-inch cyclotron with the activity appearing in the cobalt extraction as a $Ni^{64}(p, \alpha)Co^{61}$ reaction. Absorption measurements in aluminum gave a maximum β-energy of about 1.1 Mev with no indication

of a gamma-ray. This problem was carried out under the auspices of the Atomic Energy Commission.

E7. Some Excitation Functions of Alphas and Deuterons on Bi. ELMER L. KELLY AND E. SEGRÈ, *University of California at Berkeley.*—As a part of a systematic investigation of excitation functions the absolute cross sections for the reactions $(\alpha, 2n)$, $(\alpha, 3n)$, (d, p), $(d, 3n)$, (d, n) on Bi will be presented. The energy of the projectiles ranges up to 38 Mev for the α-particles and up to 19 Mev for the deuterons. The thresholds for $(\alpha, 2n)$, $(\alpha, 3n)$, and $(d, 3n)$ reactions are respectively 19 Mev, 29 Mev, and 12 Mev. The technique used is the usual one of bombarding stacked foils, but some improvements have been made on the definition of energy and measurement of current. Also the stopping power of Bi and other substances used has been redetermined with respect to Al. The relation of these curves to present theories on excitation functions and to other experimental data[1] on the subject will also be discussed. This paper is based on work performed under contract W-7405-Eng-48, with the Atomic Energy Commission, in connection with the Radiation Laboratory, University of California.

[1] Tatel and Cork, Phys. Rev. **71**, 159 (1947).

E8. The γ-Instability of Mesons. R. J. FINKELSTEIN,* *University of California at Berkeley.*—The following examples of γ-instability are investigated: (a) $M_0 \rightarrow \gamma_1 + \gamma_2$, (b) $M_1 \rightarrow \gamma_1 + \gamma_2 + \gamma_3$, (c) $M_1 \rightarrow M_0 + \gamma$, (d) $M_1^{\pm} \rightarrow M_0^{\pm} + \gamma$, where M_0 and M_1 mean a pseudoscalar and a (heavier) vector meson, respectively, and the superscript $\pm$ indicates the charge, if there is one. If the coupling constant and meson masses appropriate to the Schwinger mixture are used, the lifetimes are found to be: $\tau_a = 1 \times 10^{-16}$ sec., $\tau_b = 2 \times 10^{-11}$ sec., $\tau_c = 1 \times 10^{-18}$ sec., and $\tau_d = 4 \times 10^{-18}$ sec. In all cases except (b) the calculation leads to logarithmically divergent integrals.

* On leave from Argonne National Laboratory, Chicago, Illinois.

E9. On the Scattering of Neutrons by O_2 Molecules. OTTO HALPERN, *Columbia University.*—The theoretical analysis of the scattering of monochromatic neutron beams by gaseous O_2 molecules allows separating the contributions arising from nuclear and magnetic forces. The nuclear part must be subdivided into elastic, unelastic and hyper-elastic collisions, each of which show a characteristic dependence on the wave-length of the incident neutrons and on the temperature of the scattering gas. The elastic part in particular is very small for neutron velocities down to the thermal range, but increases rapidly with the wave-length and exceeds twice the cross section of an 0 atom for wave-lengths near 5A. The magnetic scattering processes, though always incoherent, do not lead to any appreciable energy transfer by the neutrons; they become quantitatively very important with increasing neutron wave-lengths. A comparison of the theory with recent experimental data will be given.

E10. Specific Ionization of 25- to 300-Kv Electrons. ROBERT H. FROST, *University of California at Berkeley.*—Measurements of the specific probable ionization of 25- to 300-kv electrons have been made in hydrogen, helium, and argon, and in the water-alcohol vapor used in a Wilson cloud chamber. Following the method used by Carl E. Nielsen for air, the ionization was measured by counting the water droplets formed in the chamber under known conditions of condensation efficiency, and the momentum determined by measuring the diameter and pitch of the helical tracks in a magnetic field. Ionization in the vapor was determined by using different pressures of the same gas in the chamber, assuming that the ionization in the gas was proportional to its pressure. Pictures have been taken with hydrogen gas at pressures ranging from 12 cm to 70 cm of mercury. At the lower pressure the ionization in the vapor is twice the ionization in the hydrogen, so that the value obtained for the former was not too sensitive to uncertainties in the value for the latter. Corrections were made for the background, for the superposition of drop images, for the elongation of the track produced by the expansion of the chamber, and for the variable time of entry of electrons into the chamber.

E11. Stability of a Reciprocating Electron. F. W. WARBURTON, *University of Redlands.*—The reciprocal force of two electrical charges[1] which is independent of the observer, provides a magnetic force which can balance the electrostatic repulsion and describe a stable electron. This occurs for the simplified model, in which the two halves of the electron are separated a distance r, when they revolve about their centroid with speed $c/2$. Using the mass equivalent of their electrostatic and magnetic energy, one finds $r = 1.4(10)^{-13}$ cm. This type of stable electron has the small magnetic moment of 1.7 nuclear magnetons, and has no intrinsic angular momentum since the net force on each half is zero and no mass is attributed to each part alone. When gyromagnetism and "spin" are described by using the magnetic potential energy[2] in the Lagrangian and Hamiltonian functions, no spin magnetic moment and momentum are needed in addition to orbital magnetic moment and momentum. The concept of mass as the external aspect of the internal electrical energy alone is strengthened when mechanical mass originates from the internal electrical energy of the non-massive electrical parts of an elementary particle.

[1] F. W. Warburton, Phys. Rev. **69**, 40 (1946); **70**, 86 (1946).
[2] F. W. Warburton, Phys. Rev. **63**, 460A (1943).

E12. Noise in Electrometer Tubes. A. THEODORE FORRESTER, *University of Southern California.*—In some recent papers expected noise in electrometer tubes has been calculated by using simple triode formulae. According to a theory developed by North[1] but applied only to screen grid tubes, the interposition of a positive grid between the cathode and plate causes the ratio of mean square plate current fluctuation to average plate current to be greater than in a negative grid triode. Since the electrometer tubes invariably contain a positive space charge grid which draws a current large compared to the plate current, it is necessary to apply the ideas of North to the calculation of the plate noise. Sufficient data were available[2] for the Western Electric D-96475 to make possible a calculation of the expected shot noise. This was found to be equivalent to an

input resistor of 815,000 ohms, 11.4 times the value obtainable from the usual triode term $3/g_m$. An approximation to the noise in similar tubes may be obtained by supposing the plate current fluctuations to be temperature limited shot noise, i.e., $d\langle i^2\rangle_{hf} = 2eI_p df$.

[1] D. O. North, RCA Rev. 5, 244 (1940).
[2] D. B. Penick, Rev. Sci. Inst. 6, 115 (1935).

E13. Rise Time of Pulses in Silver Chloride Crystal Counters. ROBERT HOFSTADTER, *Princeton University.*—The rise time of pulses[1] in silver chloride has been studied at the temperature of liquid nitrogen. The pulses are produced by high energy electrons released in the crystal by gamma-rays from radium. The first crystal studied was 2 mm thick. With applied voltage of 1000 volts, the rise time of the largest pulses, observed by eye on an oscilloscope screen, was the rise time of the amplifier. This amplifier, designed by W. C. Elmore, has a rise time of about 1.5×10^{-7} second. Thus the crystal pulse rises in about 1.5×10^{-7} second or less. If the rise time for the largest pulses is taken to be the time required for an electron, released by the high energy particle near the cathode, to drift through the crystal to the anode, an elementary calculation gives a rise time of 1.7×10^{-6} second, under the conditions specified. Results of the Frolich-Mott theory were used in this calculation.[2] For a rise time of 1.5×10^{-7} second, the mobility is calculated as 270 cm/sec. per volt/cm. Preliminary investigation of a second crystal, one centimeter thick, will be discussed.[3]

[1] P. J. Van Heerden, *The Crystal Counter*, Dissertation, Utrecht, 1945.
[2] H. Frohlich and N. F. Mott, Proc. Roy. Soc. **171A**, 496 (1939).
[3] This work was partially supported by the U. S. Navy.

SUPPLEMENTARY PROGRAMME

SP1. Production of High Energy Neutrons by Stripping, II. Angular Distribution. R. SERBER, *University of California at Berkeley.**—Continuing from abstract A11 one can see that similarly, most of the neutrons will come off at an angle to the direction of the deuteron beam less than $\theta = P_1/P_0 = (d/Ed)^{\frac{1}{2}} \sim 6°$. The angular spread of the neutron beam is expected to be somewhat wider for heavy nuclei than for light ones because of the deflection of the deuteron by the Coulomb field of the nucleus, and, to a lesser extent, because of multiple scattering in the target. A nearly linear increase in half-width with Z is predicted. The calculated curves of neutron intensity as a function of angle agree well with the measurements of Helmholz, McMillan, and Sewell in regard to shape, absolute width, and variation with atomic number. In addition to the stripping process, high energy neutrons will be produced by direct nuclear encounters, and, for more distant impacts, by the dissociation of the deuteron by the Coulomb field of the nucleus. The total number of high energy neutrons produced by the former process should be comparable to the number produced by stripping, but since a considerably wider angular distribution is to be expected, these give only a small contribution to the narrow forward peak. The cross section is proportional to Z^2. These papers are based on work performed with the support of the Atomic Energy Commission.

* To be called for after paper A11 if time permits.

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Clement, Evans—No. D1
Cohen, Richard E. and R. F. Christy—No. A3
Cunningham, B. B., H. H. Hopkins, M. Lindner, D. R. Miller, P. R. O'Connor, I. Perlman, G. T. Seaborg, and R. C. Thompson—No. A8
Eckart, Carl—No. C4
English, W. N.—No. B8
Eyring, Carl F.—No. C2
Finkelstein, R. J.—No. E8
Follin, James W., Jr.—No. D5
Forrester, A. Theodore—No. E12
Forster, Harriet H.—No. D2
Fowler, W. A., C. C. Lauritsen, and T. Lauritsen—No. A2
Fretter, W. B.—No. D6
Frost, Robert H.—No. E10
Gardner, Eugene—No. D7
Gerjuoy, E.—No. E2
Halpern, Otta—No. E9
Hansen, James W.—No. B9
Helmholz, A. C., Edwin M. McMillan, and Duane Sewell—No. A10
Hofstadter, Robert—No. E13
Kelly, Elmer L. and E. Segrè—No. E7
Knudsen, Vern O.—No. C1
Lauritsen, C. C., T. Lauritsen, and W. A. Fowler—No. A4
Lauritsen, T., W. A. Fowler, and C. C. Lauritsen—No. E5
Leith, C. E., Alec Bratenahl, and B. J. Moyer—No. D14
Levine, Harold and Julian Schwinger—No. B10
Loughridge, D. H. and F. M. Millican—No. D4
Moyer, B. J., R. Hildebrand, N. Knable, T. J. Parmley, and H. York—No. D13
Neddermeyer, S. H.—No. B6
Omer, Guy C., Jr. —No. D11
Parmley, Thomas J. and Burton J. Moyer—No. E6
Powell, Wilson M.—No. A7
Raitt, R. W.—No. E3
Retallack, J. G.—No. D3
Rubin, Sylvan—No. A5
Saxon, David S. and Reina A. Hunter—No. D12
Schwarzmann, Gertrude—No. D10
Schwinger, Julian—No. B11
Seaborg, G. T., B. B. Cunningham, H. H. Hopkins, M. Lindner, D. R. Miller, P. R. O'Connor, I. Perlman, and R. C. Thompson—No. A9
Serber, R.—No. A11, SP1
Sewell, D. C., L. Henrich, and J. Vale—No. A6
Slater, J. C.—No. B1
Stephenson, S. T. and F. D. Mason—No. D9
Townes, C. H., A. N. Holden, and F. R. Merritt—No. B3
Urick, R. J.—No. E4
Warburton, F. W.—No. E11
Wiegand, Clyde—No. D8
Young, R. W.—No. C3